



### *A Steam Challenge Technical Case Study*

## REBUILDING STEAM TURBINE GENERATOR REDUCES COSTS AT A STEEL MILL

### BENEFITS

- Achieved annual electricity savings of approximately 40,000 MWh
- Saved nearly 85,000 MMBTU of natural gas per year
- Achieved annual cost savings of about \$3.3 million
- Payback of 1 year
- Reduced high-temperature water discharges into the harbor
- Decreased coke oven and blast furnace gas emissions

### APPLICATIONS

Can be applied to almost any industrial application where steam turbines are used for shaft power or to generate electricity on site. Industrial facilities with boiler systems may be able to use the thermal energy stored in condenser water discharges and other liquid streams.

### Project Summary

To remain competitive in the rapidly changing global marketplace, Bethlehem Steel Corporation (BSC), the second largest producer of steel in the United States, was looking for opportunities to improve the performance of one of the steam turbine generators at their Burns Harbor Facility in Indiana. By rebuilding the turbine to incorporate the latest steam path technology, using a portion of the warm condenser cooling water exhaust stream instead of cool lake water for boiler feedwater make-up, and injecting the low-pressure steam previously used to heat the lake water into the turbine, BSC was able to significantly increase the capacity and efficiency of the steam turbine generator system. This Steam Challenge Showcase Project resulted in annual savings of approximately 40,000 MWh of electricity, 85,000 MMBtu of natural gas, and nearly \$3.3 million. With a cost of \$3.4 million more than a standard maintenance overhaul, the simple payback for the project is just over one year. The project also reduced high-temperature water discharge into the harbor, and decreased coke oven and blast furnace gas emissions.

### Plant Overview

The Burns Harbor Facility, located on about 1,700 acres on the shores of Lake Michigan, is BSC's largest and most efficient plant. Built in 1964, the plant, which employs 6,000 workers, is capable of an annual production of 5.3 million tons of hot-rolled sheet, cold rolled sheet, and steel plates, and is a major supplier of sheet and plate products to the automotive, machinery, and appliance markets.

### Project Background

Due to stiff global competition, domestic steel producers have been forced to improve the efficiency and competitiveness of their steel-making operations, or shut down. With daily electricity, natural gas, and potable water costs of \$300,00 at its Burns Harbor Facility, BSC realized that addressing the plant's energy costs could save money and improve the plant's competitive position.

### Project Team

Together with BSC staff, General Electric Industrial & Power Systems performed the turbine upgrades, and the U.S. Department of Energy's Steam Challenge program confirmed the resulting energy savings.



## BURNS HARBOR'S TURBINE #5



### The Old System

Steel-making involves two main raw materials, coal and iron ore pellets. The coal is initially placed in an oxygen-free coke oven, where it is baked for 18 hours and converted to coke. The coke, along with iron ore pellets and other raw materials, is then fed into a blast furnace, where a hot air blast ignites the coke and melts the pellets. The resulting molten iron is then transported to the steel-making shop, where it is charged into a Basic Oxygen Furnace (BOF) along with steel scrap and fluxes. Gaseous oxygen is blown into the BOF, generating high temperatures and chemical reactions that oxidize the impurities of the metal, converting the iron into molten steel. The molten steel is then molded into semi-finished slabs, which are then cut into individual lengths, and transported to slab yards.

The Burns Harbor Facility has three BOFs capable of producing approximately 300 tons of molten steel in 30 minutes. The steel making process is electric-intensive, and BSC generates much of the needed electricity on-site using six steam turbines. These turbines are supplied with steam generated in boilers that are primarily fueled with coke oven and blast furnace gases, by-products of the steel-making process. The boilers are also fueled with natural gas when by-product gases are not available. The existing power generation system used treated lake water for boiler feedwater make-up. This water was heated to 240°F using low-pressure steam.

Before the turbine upgrade, BSC did not have sufficient generating capacity to consume all of the blast furnace gas during an outage of one of the other turbine generators. This resulted in the by-product gases and their energy being released into the atmosphere, and forced BSC to purchase power, thereby incurring substantial demand and energy charges. Turbine #5 was targeted for performance improvement because it was due for a maintenance overhaul, and because it already had a generator that was oversized.

### Alternatives Considered

BSC considered a number of options to improve the efficiency and upgrade the capacity of turbine #5. Work normally performed during a scheduled

## NEW LOW-PRESSURE STEAM LINE



maintenance shutdown, such as cleaning buckets, would have increased the output from 42 to 44 MW. Replacement of some turbine components would have brought power output up to 46 MW. Output could have been increased to 48 MW, using the normal-operation steam flow, if the turbine were redesigned to incorporate the latest steam path technology. Because of the need for increased generation capacity, BSC elected to redesign the turbine, substantially increasing the turbine's efficiency and capacity.

Another system modification involved changing the source of the boiler feed-water make-up from cool lake water to a warmer condenser cooling water exhaust stream. The old system heated 42,000,000 gallons of lake water per month with low-pressure steam. Substituting the condenser cooling water exhaust stream that was 20°F warmer reduced low-pressure steam usage, thus allowing the excess steam to be injected into the redesigned turbine, thereby increasing its output.

### The New System

BSC accomplished three goals with the turbine redesign: increasing the efficiency and output under normal operation, increasing full-load capacity for operation when other turbines were offline, and allowing the use of excess low-pressure steam in the turbine. To increase efficiency and capacity, the turbine redesign focused on controlling steam flow losses and increasing steam flow capacity. The first objective was accomplished by optimizing nozzle and bucket areas to better direct and capture the steam's available energy. The second objective was accomplished by installing an additional throttle valve and nozzles to the existing valve rack and removal of the second stage buckets and diaphragms. The turbine was also modified to allow for the inlet of up to 40,000 lbs/hr of low-pressure steam, previously used to heat the lake water. The flow modifications changed the dynamic loading throughout the high and low pressure sections of the turbine, requiring replacement of components such as diaphragms, nozzles, buckets, and a new admission valve.

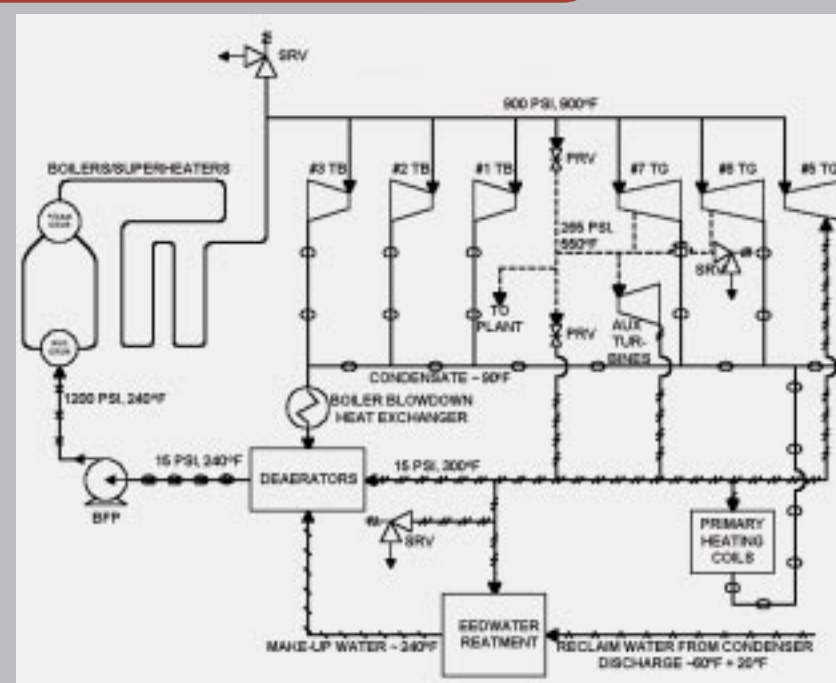
A 100-foot, 14-inch diameter steam line was installed to supply the excess low-pressure steam to the turbine. This resulted in approximately 0.7 MW of increased output. Additional changes to the pumping system were also required for the conversion from lake to condenser water. The entire power station steam flow, including changes made during this project, is shown in the diagram to the left.

Under normal operating conditions, the modified turbine generates about 48 MW. When one of the other turbines is experiencing an outage, some of the excess steam is piped to the upgraded turbine, which can now generate as much as 59 MW.

### Results

The upgraded turbine and other system modifications resulted in significant energy and cost savings. Annual electricity savings of approximately 40,000 MWh were realized, and nearly 85,000 MMBtu of natural gas are conserved each year. Cost savings include \$1.45 million from reduced demand charges

## POWER STATION STEAM FLOW DIAGRAM



resulting from the increase in turbine capacity, \$1.3 million from efficiency gains in the turbine, \$270,000 from avoided temporary power costs when other turbines are down, and \$280,000 from reduced natural gas costs resulting from the switch to condenser water. Total annual cost savings are about \$3.3 million, based on 1995 energy costs. With a cost of \$3.4 million more than a standard maintenance overhaul, the simple payback for this project was just over one year. In addition to the energy and cost savings, the project reduced high-temperature water discharges into the ship harbor, and decreased coke oven and blast furnace gas emissions.

## ENERGY AND COST SAVINGS

Project Implementation Costs	\$3,400,000
Annual Energy Costs Savings	\$3,300,000
Simple Payback (years)	1.03
Annual Energy Savings (MWh)	40,000
Annual Natural Gas Savings (MMBtu)	85,000

## TOTAL ANNUAL EMISSIONS REDUCTIONS

CO <sub>2</sub>	99,700,000 lbs
Carbon Equivalent	27,200,000 lbs
SO <sub>2</sub>	294,000 lbs
NO <sub>x</sub>	370,000 lbs
PM-10	11,600 lbs
VOC	1,450 lbs
CO	14,000 lbs

## Lessons Learned

A number of valuable lessons were learned from this project. First, if equipment is scheduled for a maintenance overhaul, consideration should be given to making upgrades that go beyond standard maintenance to improve the performance of the equipment. Second, attention should be paid to energy rate structures in utility bills. Sometimes projects that result in efficiency gains can dramatically reduce energy costs. Finally, find ways to use "waste" heat streams and put the thermal energy to use.

## Other Applications

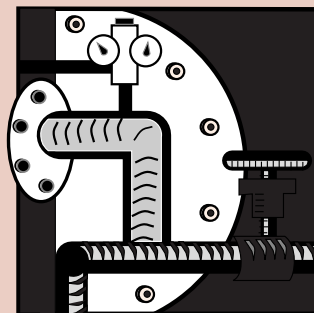
The technology used in this case study could be applied to almost any industrial application where steam turbines are used for shaft power or to generate electricity on-site. When a turbine is scheduled for overhaul, discuss upgrade options with vendors to improve system performance.

Industrial facilities with boiler systems should look for opportunities to use the thermal energy stored in condenser water discharges and other liquid streams. Process integration that matches heat sources and sinks through heat exchangers, known as pinch technology, can sometimes lead to substantial energy savings.

## INDUSTRY OF THE FUTURE—STEEL

Through OIT's Industries of the Future initiative, the Steel Association, on behalf of the steel industry, has partnered with the U.S. Department of Energy (DOE) to spur technological innovations that will reduce energy consumption, pollution, and production costs. In March 1996, the industry outlined its vision for maintaining and building its competitive position in the world market in the document, **The Reemergent Steel Industry: Industry/Government Partnerships for the Future**.

OIT Steel Team Leader: Scott Richlen (202) 586-2078



The Steam Challenge is a public-private initiative between the U.S. Department of Energy, the national non-profit Alliance to Save Energy, and several private companies and associations. It promotes the comprehensive upgrade of industrial steam systems so U.S. manufacturers can increase productivity and lower production costs.

Steam Challenge assists the steel industry and other OIT Industries of the Future by identifying near-term gains in energy efficiency these industries can achieve by adopting existing technologies.

## PROJECT PARTNERS

Bethlehem Steel Corporation  
Burns Harbor, IN

General Electric Industrial  
& Power Systems  
Schenectady, NY

## FOR ADDITIONAL INFORMATION, PLEASE CONTACT:

The OIT Information Clearinghouse  
Phone: (800) 862-2086  
Fax: (360) 586-8303  
<http://www.oit.doe.gov/steam>

Visit our home page at  
[www.oit.doe.gov](http://www.oit.doe.gov)

Please send any comments, questions, or suggestions to  
[webmaster.oit@ee.doe.gov](mailto:webmaster.oit@ee.doe.gov)

Office of Industrial Technologies  
Energy Efficiency  
and Renewable Energy  
U.S. Department of Energy  
Washington, D.C. 20585



DOE/GO-10099-763  
April 1999